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An AVHRR Data Set for the Arctic Leads ARI

F. M. Fetterer
J. D. Hawkins
Remote Sensing Branch
Ocean Sensing and Prediction Division
Ocean Science Directorate

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The Naval Oceanographic and Atmospheric Research Laboratory (NOARL) Remote Sensing Branch is selecting and processing Advanced Very High Resolution Radiometer (AVHRR) data to support the science objectives of the Office of Naval Research (ONR) Arctic Leads Accelerated Research Initiative (Arctic Leads ARI). Imagery is selected using hard copy prints from the Navy/National Oceanic and Atmospheric Administration (NOAA) Joint Ice Center. An attempt is made to select imagery so that most of the Arctic is covered every 3 days. Imagery from NOAA's Satellite Data Services Division is calibrated and mapped to a stereographic projection identical to that used for Special Sensor Microwave Imager (SSM/I) data by the National Snow and Ice Data Center. The Arctic is covered in 2 grids of 1 km pixel size. Three years worth of imagery will be processed. At present, processing for 1989 is underway.

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Abstract

The Naval Oceanographic and Atmospheric Research Laboratory (NOARL) Remote Sensing Branch is selecting and processing Advanced Very High Resolution Radiometer (AVHRR) data to support the science objectives of the Office of Naval Research (ONR) Arctic Leads Accelerated Research Initiative (Arctic Leads ARI). Imagery is selected using hard copy prints from the Navy/National Oceanic and Atmospheric Administration (NOAA) Joint Ice Center. An attempt is made to select imagery so that most of the Arctic is covered every 3 days. Imagery from NOAA's Satellite Data Services Division is calibrated and mapped to a stereographic projection identical to that used for Special Sensor Microwave Imager (SSM/I) data by the National Snow and Ice Data Center. The Arctic is covered in 2 grids of 1 km pixel size. Three years worth of imagery will be processed. At present, processing for 1989 is underway.

Acknowledgments

We extend thanks to those who attended the Arctic Leads ARI Remote Sensing Working Group meetings and offered suggestions and good humor: Duane Eppler, Jeff Key, Ron Lindsay, Jim Maslanik, Drew Rothrock, Axel Schweiger, Bernard Walter, and Ron Weaver. The AVHRR data is being capably processed by Bobby Grant of Sverdrup Technology. Rich Goldcamp, also of Sverdrup Technology, provided programming support. We are grateful to Denny Farmer and Duane Eppler, of NOARL's Polar Oceanography Branch, for help in evaluating some of the AVHRR imagery. Finally, Dave Benner and Cheryl Bertoia provided the hard copy imagery without which the project would not have been possible. We thank them and the Navy/NOAA Joint Ice Center for their help. This project is supported by ONR under Program Element No. 61153N, Dr. Thomas Curtin, Program Manager.

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Introduction

In January of 1989, a workshop was held at the University of Washington's Applied Physics Laboratory (UW/APL) in order to plan the Office of Naval Research (ONR) Arctic Leads Accelerated Research Initiative (Arctic Leads ARI). The goal of the 5-year Arctic Leads ARI is a more thorough understanding of the oceanography, meteorology, and ice dynamics surrounding lead formation and evolution. The initiative includes a field experiment that will take place, at this writing, between 10 March and 30 April 1992.

At the initial Arctic Leads ARI meeting, a Remote Sensing Working Group was formed. This group is focused on issues which can be addressed through remote sensing observations, such as the relationship of lead patterns to the wind field, the regional distribution of lead width, orientation, and fractional area over time, and the computation of surface fluxes over large areas. To support the science objectives of the Remote Sensing Working Group, as outlined in that group's workshop report, a satellite data set is needed. At present, the Advanced Very High Resolution Radiometer (AVHRR) is the only sensor acquiring readily available digital data with Arctic wide views at a resolution that can be used for lead statistics retrieval. A discussion concerning what sort of data set would best meet the needs of the group took place at the Cooperative Institute for Research in Environmental Sciences (CIRES) on the University of Boulder campus in September 1989. This discussion resulted in a Naval Oceanographic and Atmospheric Research Laboratory (NOARL) proposal to ONR for the creation of an AVHRR data set. Under the proposal, imagery will be collected and processed on three scales:

- A local scale, on which Landsat imagery can be compared with AVHRR imagery in order to ascertain the effect of sensor resolution on the extraction of lead characteristics.

- A synoptic scale, on which the response of lead patterns to storms can be observed.

- A basin-wide scale, on which regional, seasonal, and annual variability in lead patterns can be observed throughout the Arctic.

The synoptic scale imagery will be acquired "on demand" at the request of the Arctic Leads ARI Atmospheric Research Group. The basin scale imagery will comprise a 3 year data set selected from the National Oceanic and Atmospheric Administration (NOAA) archives and processed at NOARL. Initially, the data set was to cover the years 1989, 1990, and 1991. This may be changed to 1987, 1988, and 1989 so that the Arctic Leads ARI data set can also serve as an Earth Observing System (EOS) Pathfinder data set. This technical note explains how imagery is being selected and processed for the basin scale data set. At present, data for January, February, and April 1989 has been processed. Processing for the rest of 1989 is underway.

AVHRR Sensor and Data Characteristics

The AVHRR is a cross-track scanning instrument flown continuously on the NOAA polar orbiting series of satellites since October 1978. Table 1 lists NOAA satellites carrying the AVHRR during the time period of interest to the Leads ARI.

Table 1. Active periods for recent NOAA polar orbiting satellites.

Satellite	Launch Date	Active Period
NOAA-9	12 Dec 84	25 Feb 85 - 7 Nov 88
NOAA-10	17 Sep 86	17 Nov 86 - present
NOAA-11	24 Sep 88	8 Nov 88 - present
NOAA-12	12 May 91	Awaiting launch

The orbital period of the satellites is about 102 min, and the orbital inclination is about 99°.

AVHRR data can be obtained in three forms: HRPT (High Resolution Picture Transmission), LAC (Local Area Coverage), and GAC (Global Area Coverage). HRPT direct readout data is continuously broadcast from the satellite and is obtainable for areas within a ground station mask. For instance, the Gilmore Creek, Alaska ground station receives HRPT data covering the Beaufort, Bering, Chukchi, and East Siberian Seas. LAC data is HRPT data that has been recorded on board the satellite for playback when the satellite is within range of a command data acquisition (CDA) station. Up to 10 min of LAC data can be recorded during each orbit. GAC data is reduced resolution data acquired during an entire orbit and stored for playback on command. Its resolution cell size of about 4 km at nadir makes GAC unsuitable for most purposes of the Arctic Leads ARI.

The spectral bandwidth of each of the AVHRR channels is given in Table 2. IR channels are designed for a NEdT (noise equivalent differential temperature) of 0.12 K at 300 K, and visible channels for a signal-to-noise ratio of 3:1 at 0.5% albedo. More information on channel performance and calibration parameters can be obtained in NOAA Technical Memorandum NESS 107, the NOAA Polar Orbiter Data Users Guide, and Abel (1990).[1,2,3]

Table 2. Bandwidths (in micrometers) for AVHRR channels.

Channel	NOAA-10	NOAA-9,-11	IFOV (milliradians)
1	0.58 - 0.68	0.58 - 0.68	1.39
2	0.73 - 1.10	0.73 - 1.10	1.41
3	3.55 - 3.93	3.55 - 3.93	1.51
4	10.50 -11.50	10.30 -11.30	1.41
5	Ch. 4 repeated	11.50 -12.50	1.30

Given an altitude of 833 km and an instantaneous field of view of 1.4 milliradians, the nominal AVHRR sensor resolution is 1.1 km at nadir and about 4 km at the scan limbs (at a satellite scan angle of 55.4° from nadir). There are 2048 samples from each channel across each scan. The sensor swath width is about 2900 km, or 26° of latitude. The data are recorded with 10-bit precision. The range of the radiometer is approximately -80°C to 40°C, and the brightness temperature resolution of the instrument is about 0.12°. Strictly speaking, however, resolution varies with the temperature of the scene being observed and with channel, since the sensor response is not linear with temperature.

AVHRR Data Selection for the Leads ARI

The Arctic Leads ARI Project Manager and the Remote Sensing Working Group determined that the goal of AVHRR data selection would be complete coverage of the Arctic every 3 days for a period of 3 years, with the understanding that spotty LAC coverage, as well as cloud cover, would prevent this goal from being reached for certain areas and time periods. The Navy/NOAA Joint Ice Center (JIC) has a standing request with NOAA for complete Arctic LAC coverage every day. However, NOAA must satisfy other user requests as well, with the result that LAC passes over the Barents, Kara, and Laptev Seas occur an average of 2 or 3 times per week. Seas within the Gilmore Creek station mask, on the other hand, are well-sampled with HRPT data from at least 4 or 5 passes each day retained on digital tape.

AVHRR data is archived on digital tape by the Satellite Data Services Division (SDSD) of the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) in Camp Springs, MD. To select the most cloud-free data from the archive, it is necessary to examine hard copy prints of the imagery. The prints are usually made using channel 4 (IR) during the arctic winter, and channel 2 (visible) in summer. SDSD was visited in March of 1990 by Jeff Hawkins, Florence Fetterer, and Ron Lindsay in order to ascertain the best method of searching the archives and selecting digital imagery for processing at NOARL. At SDSD, we found the hard copy archive difficult to use for our purpose because there were no latitude/longitude grids on the imagery to aid in locating the area covered. In addition, there were very few hard copies of LAC imagery, and HRPT copies were few in number as well. Fortunately, the JIC also has lines to the Gilmore Creek ground station for the reception of data. Because AVHRR is JIC's primary tool for ice analysis and forecasting, the JIC hard copy holding is quite extensive. JIC makes a hard copy of almost every HRPT and LAC pass. David Benner, JIC Technical Director, has contributed greatly to the Arctic Leads ARI data collection effort by sending to NOARL all hard copies in the JIC archives for 1989. These have been examined and will be returned to JIC.

Image data for a given satellite pass is evaluated (using a hard copy) on the basis of how much of each sea is covered by the pass, and how cloud-free the image is. Images are from 1 to 3 frames long. Each frame is about 3 min of data that covers about 9° of latitude. An ascending pass that started at 70°N over Alaska, for instance, would cover just the Beaufort if only 1 frame long, or the Beaufort, Chukchi, East Siberian, Laptev, and some of the central Arctic if 3 frames long. The time and orbit printed on each hard copy is noted along with the seas covered by the image; a ranking of 1 to 5 for how well the image covers each sea; and a ranking of 1 to 5 for how cloud-free each sea appears in the image. For instance, a rank of 5-2 for the Beaufort Sea means that only about 40% of the Beaufort is covered by the image, but 100% of that is cloud-free. All images are examined but a "first cut" is made at this time by passing over those images that are clearly of no value to the Arctic Leads ARI. A printout of the NESDIS archive holdings (obtained using the SDSD Electronic Catalogue Service) is searched for each image using orbit and time information, since only about 70 to 80% of hard copy images have corresponding files in the digital archive.

The image evaluations are compiled in spreadsheets for each month. Appendix A contains the spreadsheets for 1989. Those for the remaining 2 years will be distributed as supplements to this technical note. Using the spreadsheets, an attempt is made to select imagery so that the entire Arctic is covered every 3 days. The Arctic is divided into 2 large grids (see section on image grids) so our nominal objective is to choose about 10 images for each grid per month. This is rarely enough to satisfy the sampling requirements, so a compromise must be made to obtain reasonably good coverage without processing an inordinate amount of imagery. Those images that are judged superior (marked by one or two asterisks) are chosen first, then those that combine wide coverage with little cloud cover. Generally, passes which cover a large area are favored over shorter passes that may be better in terms of cloud cover. Overall, coverage of the Beaufort and Chukchi Seas is good in 1989 except in the cloudiest month of August, but coverage of the Kara Sea and Barents Sea is scant. Since the needs of individual investigators may not be met by the selected data set, Appendix A is included so that additional passes can be selected if necessary.

Unprocessed imagery can be ordered directly from SDSD at the following address:

NOAA/NESDIS/NCDC
Satellite Data Services Division
Princeton Executive Center, Rm 100
5627 Allentown Road
Washington, D.C. 20233
(301) 763-8400

The NOAA Polar Orbiter Data Users Guide, as well as information on how to use the dial-up Electronic Catalogue Service, can be obtained from this office.

Image Processing

NOARL receives AVHRR data from NOAA/SDSD on computer compatible tapes in Level 1B form. Level 1B processing at NOAA entails appending earth location and calibration data to the senso data. At NOARL, the calibration data is applied to the sensor data, and the image is mapped to a projection using the earth location data. NOARL processing is done on the Interactive Digital Satellite Image Processing System (IDSIPS) using a VAX 8350 and International Imaging Systems (I^2S) image processing hardware and software.

Calibration, or the conversion of raw data to albedo and brightness temperature, takes place using procedures similar to those set forth in NOAA Technical Memorandum NES 107, "Data Extraction and Calibration of TIROS N/NOAA Radiometers" and in the NOAA Polar Orbiter Data Users Guide.[1,2] For channels 3, 4, and 5 raw count values are converted to radiances using a straight line approximation to calibration from on-board observations of space and an internal blackbody. Each possible raw count value of 0 to 1023 on the NOAA Level 1B data tape is matched with a radiant energy value in a look-up table. Energy is then converted to brightness temperature based on the inverse of Plank's function. A nonlinear correction to temperature is applied to channels 3, 4, and 5 using the coefficients for each channel given in NOAA Technical Memorandum NESS-107 (and in periodic updates from NOAA).[1]

Brightness temperature is then converted to output counts using the equation:

$$N = (10(K-273.16)) + 500$$

where N is output count value and K is brightness temperature in degrees Kelvin. Output count values are stored in short integer (16 bit) form. Count values can be converted to degrees Kelvin using:

$$K = ((N-500)/10) + 273.16$$

or to degrees Centigrade using:

$$C = (N-500)/10$$

where C is degrees Centigrade. The result is 0.1° per count, with a count of 500 equal to 0°C. Note that if the temperature observed is less than -50°C, the count value will be negative. Also note that if the count values of 16-bit processed imagery are to be displayed using hardware with an 8-bit deep image plane, the 16-bit images must be scaled to 8-bit images in some fashion.

Channels 1 and 2 are processed by converting raw counts to albedo using a straight line approximation based on prelaunch calibration. Albedo is expressed as a percentage of that for a perfectly reflecting Lambertian surface illuminated by an overhead sun. No corrections are made for sun angle or atmospheric effects. Each output count in the processed data is 0.1%, with a count of 500 equal to 50% albedo, 600 equal to 60% albedo, and so forth.

Imagery is warped to a ground-plane projection using position tie points embedded in the scan lines of the Level 1B data. Tie points are calculated using Brouwer mean orbital elements from orbital information provided by the North American Air Defense Command (NORAD). Tie point accuracy depends on factors such as how accurately the satellite has been tracked, how long it has been since an update, and the accuracy of the satellite clock. To improve upon the navigational accuracy given by the NESDIS tie points, each image is displayed with a graphics overlay of the coastline from the World Vector Shoreline (WVS) data base. If any coastline visible in the image does not match the graphics display, the image is shifted or "nudged" for the best possible match. Often a perfect match is not possible everywhere. This is especially true along the north coast of Greenland, where the WVS is itself in error by several kilometers.

Image Grids

The Arctic Leads ARI basin scale imagery is warped to the same projection and aligned with the same grid as that used by the National Snow and Ice Data Center (NSIDC) for Arctic SSM/I data. This will facilitate comparisons between SSM/I and AVHRR data. Grids with other projections were considered. For instance, Fleet Numerical Oceanography Center (FNOC) atmospheric fields and Polar Ice Prediction System (PIPS) ice forecasts are available on a grid with a polar projection true at 60°N. However, we decided that since this and other grids considered are relatively coarse compared with the SSM/I grid, the SSM/I projection was the better choice.

The projection used for the SSM/I grid is described in the DMSP SSM/I Brightness Temperature Grids Users Guide Section F, "SSM/I Polar Grids".[4] Briefly, the projection is polar stereographic with the map plane at 70°N. Distortion at the pole is 3%. The north polar SSM/I grid is aligned with the 135°W, 45°E meridian (Fig. 1). SSM/I products have grid cell sizes of 12.5 km, 25 km, 50 km, and 100 km. To match the SSM/I grid alignment and cover most of the Arctic with higher-resolution AVHRR data, it is necessary to use 2 grids (Fig. 2). The Pacific grid covers the Beaufort, Chukchi, and East Siberian Seas, while the European grid covers the Barents, Kara, and some of the East Greenland and Laptev Seas. Not all of the Laptev is covered, but we decided that this is preferable to reducing the coverage of the Barents Sea. The option of enlarging the grid was rejected because of the grid's already cumbersome size in terms of data storage requirements. Also, very few Laptev Sea images are available.

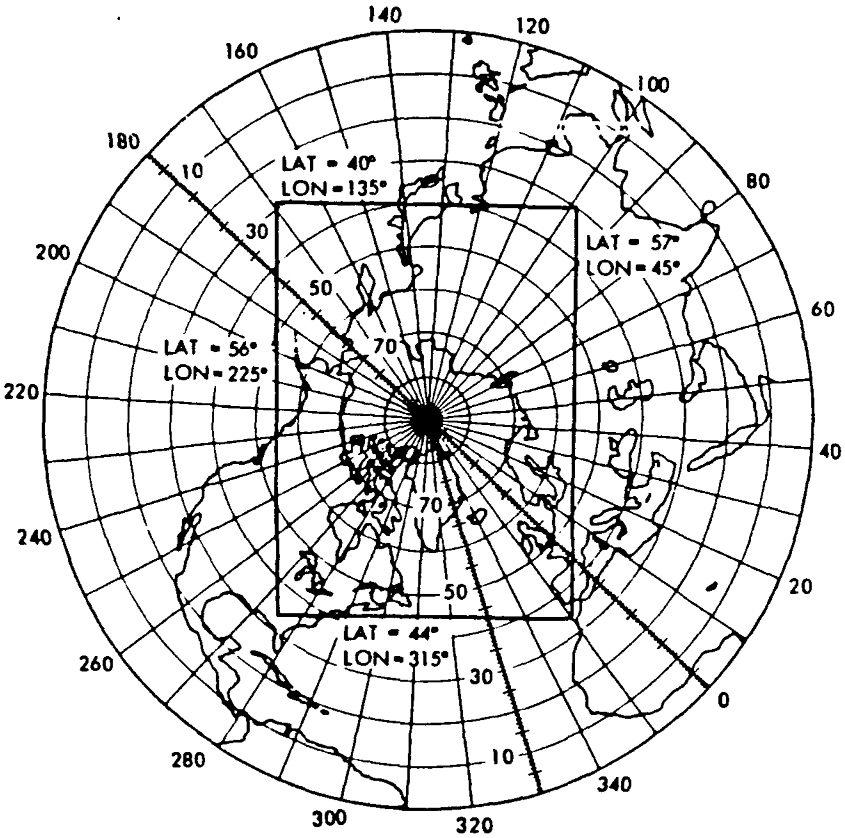

Figure 1. SSM/I North Polar Grid (reproduced from[4]).

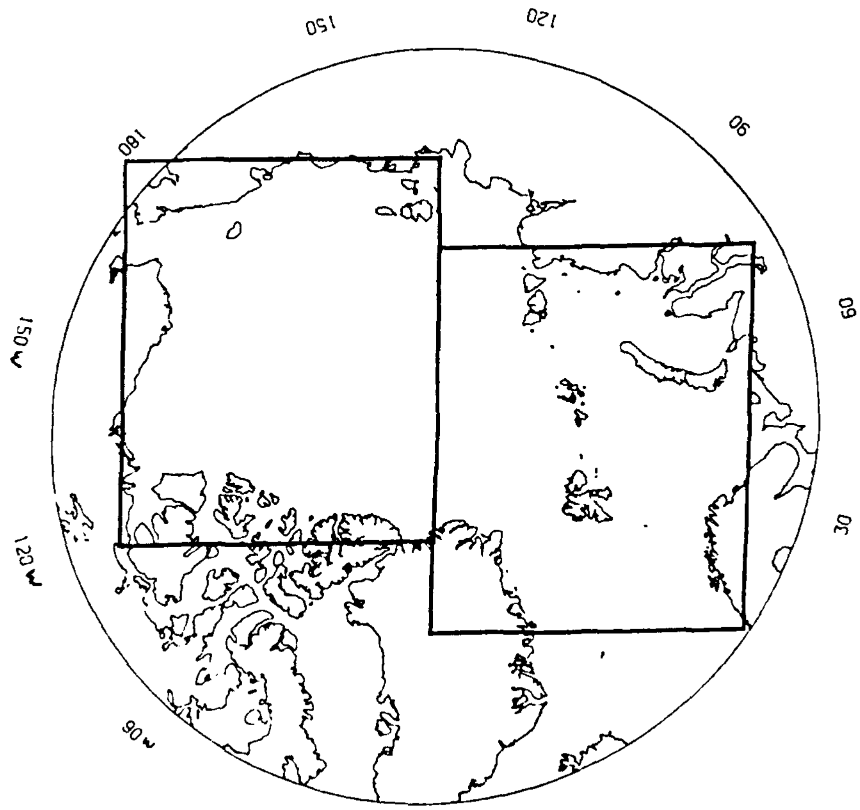

Figure 2. Arctic Leads ARI Pacific and European Grids.

The Pacific and European grids are each 2250 x 2800 pixels. The pixel size is 1 km. There is a pixel border at 135°W on the Pacific grid, and at 45°E on the European grid. This corresponds to the alignment of cells in the SSM/I grid (Fig. 3). Therefore, 25 x 25 AVHRR pixels will fit within each of the 25 km SSM/I grid cells. Appendix B contains programs for converting from pixel sample and line to latitude and longitude coordinates.

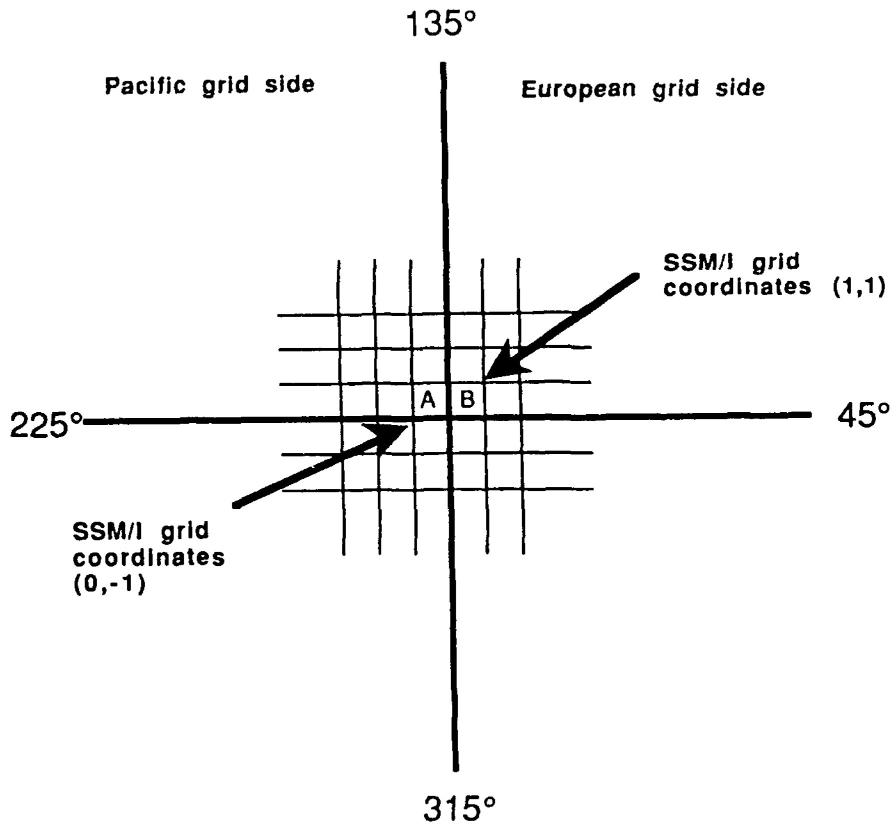

Figure 3. Relation between SSM/I grid coordinates and Arctic Lead ARI grid sample, line indexes. Grid pixel "A" is at sample 2250, line 1975 of the Pacific grid. Pixel "B" is at sample 1, line 1300 of the European grid. The SSM/I grid has its origin at the pole, and grid units are kilometers.

AVHRR swath pixels, with resolution varying from 1.1 km at nadir to 4.0 km at the scan limbs, are resampled to 1-km grid pixels using the nearest neighbor technique. Bilinear interpolation and cubic convolution were also considered as resampling methods, and a data tape with an image resampled using all three methods was sent to UW/APL and to CIRES for comparison. While all methods have disadvantages, nearest neighbor was chosen as the most suitable for the purposes of the Remote Sensing Working Group. With nearest neighbor resampling, the position of pixels in the gridded image may be shifted from their true position in the swath, but the value of those pixels is unchanged. The interpolation methods, on the other hand, smooth lead features that are often only 1-pixel wide. While this results in leads appearing less jagged than is the case with nearest neighbor, the brightness of leads will be reduced and spread into adjoining pixels. The magnitude of these changes in pixel position or value will depend on the alignment of the resampling grid with the swath. Figure 4 illustrates the difference in resampling channel 4 data using nearest neighbor and bilinear interpolation. Count values over a 10 x 11 pixel area of an image from 22 March 1988 are shown. The area was taken from near the nadir position of the sensor swath. A bright linear feature runs across the area from about column 4, row 1 to column 10, row 9.

(a)

	1	2	3	4	5	6	7	8	9	10
1	128	128	173	234	207	175	201	192	186	184
2	124	122	130	141	283	261	179	192	179	163
3	113	113	139	173	216	216	179	167	169	169
4	126	136	149	143	139	281	263	155	155	153
5	149	141	130	139	136	194	242	222	153	153
6	192	143	165	143	141	149	256	264	173	173
7	196	213	165	216	149	151	173	196	231	220
8	179	165	203	218	186	157	163	165	278	231
9	175	167	165	184	207	157	163	173	180	259
10	161	167	175	209	196	157	155	165	173	175
11	157	167	165	229	245	169	173	167	171	175

(b)

	1	2	3	4	5	6	7	8	9	10
1	127	130	154	235	219	184	198	190	184	173
2	122	123	128	182	271	223	177	179	177	170
3	114	121	141	151	205	236	179	165	168	164
4	125	139	147	141	163	250	236	169	157	153
5	147	142	134	137	144	204	251	229	172	153
6	178	149	146	142	145	157	222	254	199	169
7	198	211	192	201	164	153	[illegible]	220	231	200
8	180	174	194	219	181	158	163	199	276	245
9	173	166	165	207	198	161	162	168	193	236
10	165	169	174	198	192	162	156	164	174	176
11	159	163	168	201	224	183	165	167	173	176

(c)

	1	2	3	4	5	6	7	8	9	10
1	1	-2	19	-1	-12	-9	3	2	2	11
2	2	-1	2	-41	12	38	2	13	2	-7
3	-1	-8	-2	22	11	-20	0	2	1	5
4	1	-3	2	2	-24	31	27	-14	-2	0
5	2	-1	-4	2	-8	-10	-9	-7	-19	0
6	14	-6	19	1	-4	-8	34	10	-26	4
7	-2	2	-27	15	-15	-2	2	-24	0	20
8	-1	-9	9	-1	5	-1	0	-34	2	-14
9	2	1	0	-23	9	-4	1	5	-13	23
10	-4	-2	1	11	4	-5	-1	1	-1	-1
11	-2	4	-3	28	21	-14	8	0	-2	-1

Figure 4. Count values from an AVHRR channel 4 image of the Beaufort Sea processed using (a) nearest neighbor resampling and (b) bilinear interpolation. The difference (a-b) is shown in (c).

Imagery Distribution and Data Format

Imagery will be distributed to UW/APL (Dr. Ron Lindsay) and to CIRES, University of Colorado (Dr. Jeff Key). Initially, computer compatible tape will be used although Exabyte tape is being considered. A copy of all distributed imagery will be retained at NOARL. Arrangements are being made with NSIDC to archive the data for broader distribution. For information concerning the archive, contact:

Claire Hanson
NSIDC Data Request Services
CIRES, Campus Box 449
University of Colorado
Boulder, CO 80309
Telephone: (303) 492-1834
Telemail: NSIDC on Omnet

Table 3 lists the graphics files that will be distributed, and gives e amples of the file naming convention for image files. (All displayaole files created on the I^2S system carry the extension "image." Here "image file" refers to a file containing AVHRR data.) Both graphics and image files consist of 512 byte fixed length records with a one-record header. The header is created by I^2S software and contains I^2S-specific information. Image files are written in sample, line, and band format (although each band of the AVHRR data is given a separate file). At UW/APL, imagery will be displayed on an I^2S image processing system. The I^2S tape transfer command is used to transfer image files from the NOARL system to 6250 bpi tapes for UW/APL. At CIRES, a VAX computer system is used. The VAX DIGITAL Command Language backup command writes files from the NOARL system to 6250 bpi tapes for CIRES.

Table 3. Graphics and image file characteristics.

Graphics files

Name	Description	Data type	Size in pixels
PGRID.IMAGE	Lat,Lon grid for Pacific side	byte	2250 x 2800
PMAP.IMAGE	Coastline for Pacific side	byte	2250 x 2800
PMASK.IMAGE	Landmask for Pacific side	byte	2250 x 2800
EGRID.IMAGE EMAP.IMAGE EMASK.IMAGE	As above, for European side		
PGRID512.IMAGE PMAP512.IMAGE PMASK512.IMAGE EGRID512.IMAGE EMAP512.IMAGE EMASK512.IMAGE	As above, but fits images which have been subsampled by 6		512 x 512 375 x 467 375 x 467
P13JAN89_2124 _TRK.IMAGE	Nadir track for the 13 Jan 1989 image	byte	512 x 512

Image files

Example name (all with ext .IMAGE)	Description	Data type	Size in pixels
P13JAN89_2124_C1S	Channels 1 to 5	short integer	2250 x 2800
P13JAN89_2124_C2S	of a 13 Jan 89	short integer	2250 x 2800
P13JAN89_2124_C3S	2124 GMT image	short integer	2250 x 2800
P13JAN89_2124_C4S	mapped to the	short integer	2250 x 2800
P13JAN89_2124_C5S	Pacific grid	short integer	2250 x 2800

The graphics files can be written to graphics display planes for overlaying on image files. When the files were created, graphics were written to all 7 image planes. Therefore they can be displayed in any one or all planes. The smaller graphics files (with "512" in the file name) fit over image files that have been subsampled by 6. By subsampling, it is possible to display an entire European or Pacific grid on a 512 x 512 screen. The first tapes distributed will contain these graphics files that can be used with all distributed imagery.

Most image files will have a corresponding graphics file with a filename such as E06JAN89_0913_trk.image. This contains a plot of the nadir track for the given image. Another file with a name such as E06JAN89_0913.dat has the orbital elem)ts for the satellite pass during which the imagery was acquired, along with nadir track positions every 10 s. A listing of this file is shown in Figure 5. (Because data files cannot be copied using the tape transfer command, UW/APL will receive printouts of these files rather than the files themselves.) The satellite number indicates which NOAA satellite the elements are for: NOAA-8 is 13923, NOAA-9 is 15427, NOAA-10 is 16969, NOAA-11 is 19531. In cases where the nadir track is outside the grid, the file will contain only the orbital elements.

```
PLOT'TRACK 11-FEB-1991 09:31:29.33

LISTING FILE  p10jan89_1519.dat
IMAGE FILE    p10jan89_1519_trk.IMAGE

SATELLITE NUMBER                          19531
REVOLUTION NUMBER                         1526
MEAN ANOMALY                              .3717761
MEAN MOTION                               .8277287
MODIFIED DECAY COEFFICIENT                .0007100
ECCENTRICITY                              .0012072
ARGUMENT OF PERIGEE                       .8827872
LONGITUDE OF ASCENDING NODE               .5707038
INCLINATION                               .2747912
EPOCH (Y/M/D)                             890111

START TIME     89/01/10   15:19:55
STOP TIME      89/01/10   15:31:12
TIME INTERVAL  00:00:10

PROJECTION    POLAR STEREOGRAPHIC

CENTER LATITUDE    78.33
CENTER LONGITUDE   197.93

DEGREES/PIXEL LATITUDE    .054000
DEGREES/PIXEL LONGITUDE   .054000

SAMPLES       375
LINES         467
```

LAT	LONG	YR	JDAY	SECS	REVN
79.803	273.315	89	10	55645	1526
80.077	270.315	89	10	55655	1526
80.322	267.158	89	10	55665	1526
80.539	263.851	89	10	55675	1526
80.724	260.403	89	10	55685	1526
80.875	256.830	89	10	55695	1526
80.992	253.154	89	10	55705	1526
81.072	249.398	89	10	55715	1526
81.114	245.592	89	10	55725	1526
81.119	241.766	89	10	55735	1526
81.085	237.952	89	10	55745	1526
81.014	234.182	89	10	55755	1526
80.906	230.486	89	10	55765	1526
80.762	226.888	89	10	55775	1526
80.585	223.410	89	10	55785	1526
80.375	220.070	89	10	55795	1526
80.136	216.878	89	10	55805	1526
79.869	213.843	89	10	55815	1526
79.576	210.966	89	10	55825	1526

Figure 5. Listing of an orbital element and nadir track file.

References

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2. Kidwell, K. B. (1986). NOAA Polar Orbiter Data Users Guide. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, Satellite Data Services Division, Washington, DC. Revised Dec. 1988.

3. Abel, P. (1990). Prelaunch calibration of the NOAA-11 AVHRR visible and near IR channels. *Remote Sensing of the Environment* 31:227-229.

4. National Snow and Ice Data Center (1990). DMSP SSM/I Brightness Temperature Grids for the Polar Regions on CD-ROM, Users Guide. Cooperative Institute for Research in Environmental Sciences, University of Colorado, Boulder, CO.

Appendix A: Image spreadsheets

This appendix contains Advanced Very High Resolution Radiometer (AVHRR) image spreadsheets for each month of 1989, with the exception of May. (Part of the May hard copy set is missing. A spreadsheet for May will be created as soon as the imagery is found.) The spreadsheets are "working papers," and are included here only to aid investigators who might wonder if imagery for a particular date or place is available. Contact the authors for the orbit number and National Oceanic and Atmospheric Administration (NOAA) archive tape and file number for any pass from the spreadsheets.

To create the spreadsheets, hard copies of imagery from the Navy/NOAA Joint Ice Center were examined. For each image, the date, time, and orbit printed on the hard copy was noted. Each image was rated on a scale of 1 to 5 for how clear the image is, and for how much of each sea or seas is covered. For the months of January through April, the sea or seas covered by an image were ranked as a whole. For instance, a pass covering the Beaufort, Chukchi, and East Siberian Seas might be given a ranking of 3-4. This would indicate that about 60% of the area covered by the image is cloud-free, and the image covers 80% of all 3 seas combined. Of course, the ranking is subjective. The method was changed for later months to ranking seas individually. For instance, an image that hit the Beaufort and Chukchi might be ranked 2-5 for the Beaufort and 3-3 for the Chukchi, meaning the pass covered 100% of the Beaufort and 40% was cloud-free, while it covered 60% of the Chukchi, and 60% of what was covered was cloud-free.

Spreadsheets were created from the lists of ranked imagery to facilitate selecting imagery for the Arctic Leads ARI and ordering imagery from the NOAA archive. Each image's cloud ranking, area ranking, and satellite (NOAA 10 or 11) are shown under the sea or seas the image hits. There is an asterisk if the image is deemed especially good; two if it is excellent. The Joint Ice Center separates hard copy imagery based on whether an image is best used for their Eastern or Western Arctic Analysis. For this reason, it was convenient to divide the spreadsheets into an eastern and western half. These areas generally correspond to the European and Pacific Lead ARI grid areas (although the Lincoln Sea and central Arctic are bisected by the Arctic Lead ARI grids). As noted above, the coverage of seas was ranked jointly for the months of January, February, April, June, July, and for the western Arctic in March. For the remaining months of 1989, the ranking is separate for each sea (although imagery for the central Arctic was not ranked separately from the sea from which the pass extended into the central Arctic) and each image pass was given a separate line on the spreadsheet. For January through July, all imagery that had been evaluated was entered. Those passes that were not found in the NOAA archive catalogue were then crossed out. For August through December, only those images that were listed in the archives were entered in the spreadsheet.

Image passes that were ordered from NOAA and are being processed at the Naval Oceanographic and Atmospheric Research Laboratory are highlighted. The selection was made on the basis of cloud and area ranking, balanced by the need to keep the total number of images processed in any one month to about 20. Although the objective was to obtain complete Arctic coverage every 3 days on average, this often proved impossible, especially for the European grid.

Appendix B: Programs for grid coordinate to geographical coordinate conversion

January 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
			Western Arctic (JIC designation)						Eastern Arctic (JIC designation)				
	Grid 1	Grid 2	Beaufort	Chuckchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Green-land
Date													
1								~~3-3 11~~					
1						~~3-3 10~~							
2						2-4 10							
3			3-3 10	3-3 10									
3			4-3 10	4-3 10									
4			4-3 11				4-2 11						
5												~~4-4 11~~	~~4-4 11~~
6												4-4 11	4-4 11
7									4-3 11	4-3 11			
7												3-4 11	3-4 11
8				~~2-3 10~~	~~2-3 10~~								
9				~~4-3 11~~	~~4-3 11~~								
10			~~4-3 11*~~									3-5 11	3-5 11
10			3-5 11*	3-5 11*									
10							3-3 11						
11			3-3 11	3-3 11								3-4 11	3-4 11
11				4-4 11									
12				4-4 11*								3-5 11	3-5 11
12										5-5 11*			
13				4-4 11								4-5 11*	
13			4-5 10**	4-5 10**				4-5 10**					
14			4-4 11	4-4 11							5-4 10*		
14				4-4 11		~~5-4 10~~							
14									3-5 11	3-5 11			
15			4-4 11	4-4 11					3-5 11	3-5 11			
16				4-4 11		4-4 11			3-3 11				3-3 11
16			4-4 11*										
17										4-3 11			
17												4-5 11*	4-5 11*
18			3-3 10										

18			~~3-5 11~~	~~3-5 11~~		~~3-5 11~~							
19						2-3 10							
20			4-5 11**	4-5 11**		4-5 11**							
21									4-5 11*				4-5 11*
21										5-4 11*			
22				4-4 11		4-4 11			4-5 11				4-5 11
22				4-5 11*				4-5 11*					
23				4-5 11				4-5 11					~~4-3 11~~
23			4-5 11	4-5 11				4-5 11		5-4 11			
23												4-4 11	4-4 11
24				~~4-5 10*~~				~~4-5 10*~~		4-3 11			
24						~~5-5 10*~~							
25				4-5 10				4-5 10		4-4 11			
26						4-3 10*							
26				3-4 11				3-4 11					
27				4-4 10				4-4 10					
27				3-4 11				3-4 11					
28						~~4-2 11~~							
28						4-3 10							
29				3-5 11	3-5 11			3-5 11					
30										3-4 11			
31									3-4 11				3-4 11

February 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
			Western Arctic (JIC designation)							Eastern Arctic (JIC designation)			
	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Greenland
Date													
1			2-5 10									4-5 11	4-5 11
1			3-3 11										
2					2-5 10	2-5 10						3-5 11	3-5 11
3												4-5 11	4-5 11
4					3-3 11			3-3 11					
4				~~3-3 10~~				~~3-3 10~~					
4						~~4-5 10*~~							
7						2-4 10							5-5 11
8						~~4-5 11*~~					4-5 11*	4-5 11*	4-5 11*
8												3-4 11	3-4 11
9						~~3-5 10~~							
9					4-5 11*								
9			2-4 11										
9						4-5 11*		4-5 11*					
9					~~4-5 10*~~								
10					~~4-5 10*~~					3-4 11			
11						~~3-3 10~~							
11					2-5 10	2-5 10							
11						3-5 10							
12					2-5 10	2-5 10							
13			4-5 10										
13			~~4-5 11~~										
14						2-5 10							
14			4-5 11*										
14			4-5 11*										
15			3-4 11										
16						3-5 10							
18					5-5 10*	5-5 10*							
18					5-5 10*	5-5 10*							
18			3-3 10										

19					4-5 10	4-5 10						3-3 11	3-3 11
20			~~4-5 11~~	~~4-5 11~~								2-4 11	
20					4-5 11*								
21								~~3-4 10~~	2-5 11	2-5 11			
21												3-5 11	3-5 11
22												3-5 11	3-5 11
22									3-4 11	3-4 11			
23			4-5 10*	4-5 10*								4-4 11	4-4 11
24					~~4-5 10*~~	~~4-5 10*~~						5-5 11*	5-5 11*
25								~~5-5 11~~			5-5 11*	5-5 11*	5-5 11*
25						5-5 11*		5-5 11*					
26				~~5-5 11*~~									
26					5-5 10*			5-5 10*					
26			~~5-5 11*~~	~~5-5 11*~~									
27								5-5 10*				3-4 11	
27				5-5 11*				5-5 11*					
28									4-5 11*	4-5 11*			
28												4-4 11	4-4 11

March 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
				Western Arctic (JIC designation)						Eastern Arctic (JIC designation)			
	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Greenland
Date													
1									3-3 11				
1						~~3-3 10~~						3-2 11	3-5 11
1				4-5 11*	4-5 11*								
1			~~4-4 10~~										
2			3-2 11					2-4 11					3-3 11
2						3-4 10							
2					~~4-5 10*~~	~~4-5 10*~~							
2			3-4 11										
2				3-5 11	3-5 11								
4			3-4 10										
4									2-4 11	1-2 11			3-3 11
5				~~3-3 11~~	~~3-3 11~~								
6										~~2-3 11~~			
6				3-4 11				3-4 11					
6					~~3-4 10~~								
7			3-5 11*	3-5 11*	3-5 11*			3-5 11*					
8													~~3-3 11~~
9						3-4 10*							
10						3-3 11							
11						~~3-5 10~~							
11					4-4 11								
12						~~5-5 10*~~		~~5-5 10*~~					
14						5-5 10*		5-5 10*			5-5 10*		
14									2-3 11	2-3 11*			
15				3-5 10				3-5 10					
15				3-5 11									
16													3-3 11
16												4-5 11	
16								~~5-5 11**~~					
17													2-3 11

17													4-2 11
17						~~4-3 11~~							
17				~~5-5 10**~~	~~5-5 10**~~	~~5-5 10**~~		~~5-5 10**~~					
17			~~5-5 10~~	~~5-5 10~~									
17			4-5 11*	4-5 11*									
17				5-5 11*	5-5 11*			5-5 11*					
18													4-2 11
18			~~4-4 11*~~	~~4-4 11*~~									
18						~~5-5 10~~					~~5-5 10*~~		
18			~~5-5 10~~	~~5-5 10~~	~~5-5 10~~								
18						~~5-5 10~~					~~5-5 10~~		
18				~~4-5 11*~~	~~4-5 11*~~								
18				4-5 11	4-5 11								
19													2-3 11
19				~~4-4 10*~~				~~4-4 10*~~					
20													2-3 11
21								2-4 11*					
21												2-3 11	2-4 11
21					~~4-3 10~~	~~4-3 10~~							
21					~~4-4 10~~	~~4-4 10~~							
21				4-4 10				4-4 10					
22												2-4 11	3-3 11
23								2-3 11*					
23													2-3 11
23									3-2 11			1-3 11	3-3 11*
23				4-5 11	4-5 11								
23			~~3-4 10~~										
24													2-3 11
24									4-3 11*			1-3 11	3-2 11
24			3-4 11										
25													2-3 11
25													2-3 11
25												2-3 11	
25												3-5 11*	2-3 11

25			3-5 11										
25						~~2-4 10~~							
26													4-2 11
26									3-3 11		2-1 11	3-5 11*	4-1 11
26			~~3-5 10*~~										
26					~~3-3 10~~								
26			3-4 11	3-4 11									
27									3-3 11		2-1 11	3-5 11*	4-1 11
27												3-2 11	
27												~~4-5 11**~~	
27			~~3-5 10~~	~~3-5 10~~									
27					3-3 11								
28								3-3 11		4-3 11*			3-2 11
28													3-3 11
28												3-3 11	
29								1-4 11		1-3 11			2-2 11
29													4-3 11
29													3-3 11
29												2-2 11	
29			3-5 11	3-5 11				3-5 11					
30							2-3 11	2-3 11					
30												2-5 11	2-3 11
30					4-4 11	4-4 11							
30			3-5 11*	3-5 11*	3-5 11*			3-5 11*					
31									3-2 11*			2-3 11	2-3 11
31			~~3-5 10*~~	~~3-5 10*~~	~~3-5 10*~~			~~3-5 10*~~					

NOTE - FOR EASTERN AND WESTERN ARCTIC, SAME LINE MEANS SAME PASS (SWITCHED TO RATING EACH SEA SEPERATELY, AND DENNY HAD SOME PASSES WHICH COVERED BOTH)

April 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
				Western Arctic (JIC designation)						Eastern Arctic (JIC designation)			
	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Greenland
Date													
1						4-5 10		4-5 10					
1				4-5 11	4-5 11								
1			~~4-5 11*~~					~~4-5 11*~~					
2						3-4 10					3-4 10		
2			4-4 10*	4-4 10*				4-4 10*					
2			5-5 10*					5-5 10*					
2				3-5 10*	3-5 10*			3-5 10*		3-4 11			
3					~~4-3 10~~	~~4-3 10~~							
3			~~4-4 10~~	~~4-4 10~~				~~4-4 10~~					
3			~~4-5 10*~~	~~4-5 10*~~		~~4-5 10*~~		~~4-5 10*~~	4-3 11			4-3 11	4-3 11
3				3-5 11*		3-5 11*							
4					~~3-4 10~~								
4					3-5 10							?-4 11	
4			~~3-5 11*~~	~~3-5 11*~~		~~3-5 11*~~							
4			~~2-5 10~~	~~2-5 10~~		~~2-5 10~~							
4				3-5 11	3-5 11								
5					~~3-4 11~~							5-5 11*	5-5 11*
5			3-5 10	3-5 10						3-3 11			
5			4-5 11*	4-5 11*		4-5 11*							
6			?	?	~~(ex leads)~~	~~3-5 10~~	~~(don't kno~~	~~where)~~					
6						3-5 10							
6						~~2-5 10~~							
7					5-3 10			5-3 10					
7						~~4-5 10*~~							
7								~~4-5 10*~~					
7				3-5 11				3-5 11					
7						~~3-5 10~~							
7			~~3-5 11*~~					~~3-5 11*~~					
8					4-5 11*			4-5 11*		4-5 11			
8						5-5 10*					5-5 10*		

8				3-4 11	3-4 11			3-4 11					
8					~~3-5 11~~	~~3-5 11~~							
9						~~3-5 10~~							
9						4-5 10*					4-5 10*		
10					3-4 11	3-4 11							
10									4-4 11*			4-4 11*	4-4 11*
11								~~3-5 11~~					
11					4-5 11	4-5 11							
11						4-4 10*					4-4 10*		
12			~~3-5 11*~~			~~3-5 11*~~		~~3-5 11*~~					
13						3-5 10		3-5 10					
13						~~5-5 10*~~		~~5-5 10*~~					
13								3-5 10*					
14					~~3-5 10~~			3-5 10					
14			~~3-5 10~~					~~3-5 10~~					
15			3-5 11			3-5 11		3-5 11					
16			3-310	3-3 10	3-3 10								
16						3-5 10					3-5 10		
16			3-5 11	3-5 11									
16			~~3-5 11~~					~~3-5 11~~					
17			4-5 11	4-5 11				4-5 11					
17			3-5 11										
18			4-5 11	4-5 11				4-5 11					
18				~~3-5 11~~				~~3-5 11~~					
19			~~3-5 11~~					~~3-5 11~~				3-4 11	3-4 11
19				~~3-5 11~~	~~3-5 11~~								5-5 11*
19										3-4 11			
20			3-5 11	3-5 11				3-5 11					
20						3-4 10					3-4 10		
20			~~3-5 11~~					~~3-5 11~~					4-5 11
21			4-5 11	4-5 11				4-5 11					
21										3-4 11			
21												3-4 11	3-4 11
22										5-5 11*			5-5 11*

22												4-5 11*	4-5 11*
23			3-5 11	3-5 11									
23						3-4 10							
23			3-4 10	3-4 10				3-4 10					
24			~~4-5 11~~					~~4-5 11~~					
24			~~3-5 10~~					~~3-5 10~~					
24			~~3-5 11~~										
25				3-5 11				3-5 11					
25			~~3-4 11~~	~~3-4 11~~									
25												3-5 11	3-5 11
26				~~3-5 11~~				~~3-5 11~~					
26						3-5 10*					3-5 10*		
26											4-4 11	4-4 11	
27			~~3-5 11~~	~~3-5 11~~		2-5 10		~~3-5 11~~			2-5 10		
28						2-5 10							
28			~~3-4 10~~			3-5 10					3-5 10		
28				4-5 11	4-5 11								
28				~~3-5 11~~				~~3-5 11~~					
28			4-5 11*					4-5 11*					
29					3-5 11*			3-5 11*					
			nothing good later in month										

June 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
				Western Arctic (JIC designation)						Eastern Arctic (JIC designation)			
Date	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Greenland
1			2-5 10	2-5 10	2-5 10								
2				2-5 11		2-5 11		2-5 11					
3			2-5 10	2-5 10									
3			3-5 10	3-5 10	3-5 10								
4			2-5 10	2-5 10	2-5 10								
5			3-5 10	3-5 10	3-5 10								
6			4-5 10*	4-5 10*	4-5 10*	4-5 10*		4-5 10*					
6			4-4 10										
6			4-5 10*	4-5 10*	4-5 10*								
6			4-5 10*	4-5 10*				4-5 10*					
8								~~3-5 11~~					
9						2-5 10					2-5 10		
9					3-5 10			3-5 10					
10						~~2-5 10~~		~~2-5 10~~					
10				~~2-5 11~~	~~2-5 11~~								
11			2-5 10	2-5 10									
11						2-5 10		2-5 10					
12			2-5 10	2-5 10	2-5 10								
12			3-5 10	3-5 10				3-5 10					
13			2-5 10	2-5 10				2-5 10					
13			2-5 10	2-5 10									
14			3-5 10										
14			~~3-5 10~~	~~3-5 10~~									
15			3-5 10										
15			2-5 10	2-5 10	2-5 10								
16						2-5 10		2-5 10					
16			2-5 10	2-5 10									
17			~~3-5 11~~			~~3-5 11~~		~~3-5 11~~					
18			~~2-5 11~~	~~2-5 11~~	~~2-5 11~~								
20			3-4 10										

21						2-5 10							
22						2-5 10							
22				3-5 10				3-5 10					
23						2-5 10		2-5 10					
23			~~2-5 11~~	~~2-5 11~~				2-5 11					
24			3-5 10*	3-5 10*	3-5 10*			3-5 10*					
24					3-5 11*	3-5 11*							
24			3-5 10*	3-5 10*									
24						3-5 10							
25						2-5 10							
25			3-4 10										
25			~~3-5 10~~	~~3-5 10~~	~~3-5 10~~								
25			~~3-5 11*~~	~~3-5 11*~~	~~3-5 11*~~								
26				3-5 11	3-5 11								
27				2-5 11	2-5 11								
27			3-5 10										
28						3-5 10*					3-5 10*		
28						3-5 10* (consecutive passes)					3-5 10*		
28			2-5 10	2-5 10	2-5 10								
30					3-5 10*	3-5 10*							
30			~~3-5 11*~~	~~3-5 11*~~	~~3-5 11*~~								
30				2-5 10	2-5 10								
30			~~3-5 11*~~	~~3-5 11*~~	~~3-5 11*~~								

July 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
				Western Arctic		(JIC designation)				Eastern Arctic		(JIC designation)	
	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Green-land
Date													
1			3-4 10		3-4 10			3-4 10					
1				3-4 11	3-4 11								
2			2-5 10										
2			3-5 10	3-5 10									
2								~~3-5 10~~					
3				5-5 11*	5-5 11*								4-4 11
3													4-4 11
3			3-5 10										
4													4-4 11
4													4-3 11
5													3-4 11
6				3-5 11	3-5 11								3-5 11
6									3-3 11				3-3 11
7			3-5 10	3-5 10									
7				~~3-5 11~~	~~3-5 11~~								
8				2-5 10					4-4 11				4-4 11
8						3-5 10							4-4 11
9				2-5 10				2-5 10	2-3 11				2-3 11
9						2-5 10		2-5 10					
10									2-4 11				2-4 11
14			3-5 11					~~3-5 11~~					
15			3-5 10										
15							3-3 11	3-3 11					
16											*2-5 10*		
19													3-4 11
20			3-5 10										2-4 11
24										2-3 11			
26					4-5 11								
26					3-5 10	3-5 10							
26						4-5 10					*4-5 10*		

28						3-5 10							
28				4-5 11	4-5 11								
29			4-5 10										
29						3-5 10							
31									4-3 11	4-3 11			
31													4-4 11

August 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
Note - Every pass has its own line (within W. Arctic or E. Arctic). Those not found in the NOAA tape catalogue are not recorded he													
				Western Arctic (JIC designation)							Eastern Arctic (JIC designation)		
	Grid 1	Grid 2	Beaufort	Chukchi	East	Laptev	Lincoln	Central	Central	Lincoln	Kara	Barents	Green-
Date					Siberian			Arctic	Arctic				land
1				3-5 11									
2				2-5 11	2-5 11								
3				2-5 11									
3				2-5 11				2-5 11					
5			1-3 11	3-5 11									
6				3-4 11									
6						4-4 10							
6						4-5 10							
6						3-5 10							
7			3-4 11	3-5 11	3-4 11								
7				3-5 11									
7				3-5 11									
8			2-4 10										
9						3-5 10							
9											3-4 11		
10					3-5 10	3-5 10							
10						3-4 10							
11						4-5 10					4-5 10		
11						2-4 10							
12											2-4 10		
17			2-4 10										
17				3-4 11									
17				3-5 11	2-5 11								
18			3-3 10										
18			2-4 10										
18				3-4 11									
18			3-4 11										
23				1-4 11	2-5 11								
23				2-5 11									

23				1-4 11	2-5 11								
24			1-2 11	3-4 11									
25				1-3 11	3-4 11								
26			3-4 10*										
27			2-4 10*	4-4 10*									
27			3-5 10*										
27				3-5 11									
28				2-3 11	3-4 11								
29			2-5 11	1-5 11									

Note: Most images are over the Beaufort and Chukchi and are cloud covered. Few leads - severe melting.

There are NO good images from the Eastern Arctic for August.

September 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
Note - Every pass has its own line (within W. Arctic or E. Arctic). Those not found in the NOAA tape catalogue are not recorded he													
				Western Arctic (JIC designation)						Eastern Arctic (JIC designation)			
	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Green-land
Date													
1			2-5 10										
2					3-5 11								
2				2-5 11				2-5 11					
3			3-5 10										
4			2-5 10	2-5 10				2-5 10					
6				2-5 11				2-5 11					
7				2-5 10 +				2-5 10 +					
8				2-5 10 +				2-5 10 +					
10				2-5 10				2-5 10					
13				3-5 10 +									
13				2-5 11									
13				2-5 10				2-5 10					
14				3-5 10				3-5 10					
14				2-5 11				2-5 11					
14				2-5 11 +				2-5 11 +					
15			3-5 10	3-5 10									
15							2-4 11						
16										1-4 11 +			
17										1-4 11			
18				2-5 11				2-5 11					
19				1-4 11	2-5 11								
19				2-4 11	3-5 11								
20				2-4 10				2-4 10					
20				2-5 10				2-5 10					
20			2-5 10										
20				3-5 11				3-5 11					
20				2-5 10				2-5 10					
21				3-5 11				3-5 11					2-4 11
21				3-5 10				3-5 10					

22				2-5 10				2-5 10					
22				2-5 10				2-5 10					
22				2-5 10									
23				3-5 11									
24				2-5 11 +				2-5 11 +					
24				2-5 11				2-5 11					
24			3-5 10										
25				3-5 11				3-5 11					
25				3-5 11*				3-5 11*					
25			2-5 10										
26			2-5 10										
26			2-5 10										
27			2-5 10										
30				2-5 10				2-5 10					1-4 11

NOTE: Image quality was poor in Septemper due to clouds. Many of the entries for the Chuckchi and Central Arctic were noted by Jeff Hawkins as covering the general area of the Chuckchi. They may also cover parts of the Beaufort and East Siberian Seas, and in most cases, some of the Central Arctic. I denoted with "+" entries for which Jeff had noted that floes or leads were visible (this does NOT mean that nothing at all is visible in the other entries!)

October 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies													
Note - Every pass has its own line (within W. Arctic or E. Arctic). Those not found in the NOAA tape catalogue are not recorded he													
			Western Arctic (JIC designation)							Eastern Arctic (JIC designation)			
	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Green-land
Date													
1				2-4 10				2-4 10					
6			3-4 10										
7			3-3 10							1-4 11			
8										3-4 11			
14				2-5 10									
15			3-5 11	2-5 11									
17					2-5 11					3-5 11			
17				3-5 11	2-4 11								
17				2-5 11				2-5 11					
18			3-5 11	2-4 11									
18			3-4 11	2-5 11									
19				3-5 11	2-4 11					3-5 11			
19			3-5 10										
20			3-4 11*	4-5 11*	4-4 11*					3-4 11			
20				4-5 11	3-4 11								
20					3-4 10			3-4 10					
20						4-5 10		4-5 10					
21			3-4 11*	4-5 11*	3-4 11*					2-4 11			
21						4-5 10		4-5 10					2-4 11
21			5-5 11	3-3 11									
22				3-4 11	2-5 11					2-4 11			
22			4-5 10										
22			4-5 11	4-4 11									
22											2-5 10		
23			4-5 11	4-5 11									3-5 11
23				4-4 10	3-5 10					2-4 11			
23			4-3 10										
23			4-4 11										
24			4-5 11							3-4 11			

25											3-4 10		
25										2-4 11			
25													2-5 11
26			3-5 11									2-5 11	3-5 11
26			3-5 11										
27				3-4 10	4-5 10							1-5 11	2-5 11
27			3-5 11	2-4 11					2-5 11				
27											4-5 10*		
28			3-5 10	3-5 10						4-5 11*			
28				3-5 11				3-5 11					
28											4-5 10		
28						4-5 10							
29			4-5 10	2-3 10									3-5 11
29			5-4 11	3-5 11						4-5 11*			
29						3-5 10		3-5 10					
30			4-5 10							3-5 11			
30			3-5 10										3-5 11
31				3-5 11									

November 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies

Note - Every pass has its own line (within W. Arctic or E. Arctic). Those not found in the NOAA tape catalogue are not recorded he

			Western Arctic (JIC designation)							Eastern Arctic (JIC designation)			
	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Greenland
Date													
1			3-3 11	2-5 11									
1			3-4 10	2-5 10									
2													3-4 11
3			3-5 11							2-4 11			
4						2-5 10							
5					3-5 11								
5			3-5 10										
5			3-4 11	2-4 11									
5						2-4 10							
6			3-4 10	2-5 11	3-4 10								
6			2-2 11	3-4 11	3-5 11								
7			4-5 11*										4-4 11
7										3-4 11			
8			4-5 11*					4-5 11*		3-4 11			
8						3-5 10							4-4 11
8											4-5 10		
8			3-4 10	3-4 10	3-2 10								
8				4-4 11*	4-5 11*								
9						4-5 10					4-4 10		
9			4-3 11	4-4 11									4-4 11
9				4-5 11				4-5 11		3-3 11			
9					4-5 10								
9			3-2 10	4-5 10	4-4 10								
10			4-3 10	4-4 10	3-4 10								3-4 11
10				2-2 10	4-5 10					4-5 11*			
10			3-4 11	4-4 11	4-3 11								
10						4-5 10		4-5 10					
10			4-3 10*	4-5 10*	4-5 10*								
11						4-5						3-3 11*	5-5 11*

11			4-2 11	4-3 11	3-2 11					4-5 11			
11			4-4 11										
12						4-5 10						4-5 11	3-5 11
12			4-5 11							4-4 11			
13			4-3 11	4-5 11	3-5 11					3-5 11			
14			4-3 11	4-4 11	2-3 11					3-4 11			
14			2-3 11	4-5 11									
15			4-5 11							3-5 11			
15					3-5 11								
16			4-3 11	4-4 11	3-3 11					2-3 11			
16						3-5 10							
16											3-5 10		
16			5-5 10	3-3 10									
17				3-3 11	3-5 11								
17						3-5 10							
17											3-5 10		
17			5-4 10										
17			4-3 11	4-5 11									
17			4-4 10*					4-4 10*					
18			4-5 10*	4-3 10*						4-4 11*			
18				4-3 11	3-5 11								4-4 11
18			4-4 11*	5-5 11*	4-4 11*								5-5 11*
18			4-2 11	5-5 11	4-5 11								
18											4-5 10		
18			4-2 11	5-5 11	4-3 11								
19			5-3 10	5-5 10	4-4 10								3-5 11
19			5-4 11	5-5 11	4-3 11								
19			4-3 11	5-5 11	4-5 11					3-4 11			
19											4-5 10		
19			5-4 11	5-5 11									
20				4-5 11**	3-5 11**								
20			5-4 11	4-5 11	3-4 11					3-4 11			
20			4-4 11	5-5 11								3-4 11	2-4 11
20			5-5 10*	5-5 10*	5-3 10*								

20			5-5 11										
20				4-5 10				4-5 10					
21				4-5 10				4-5 10		3-4 11			
21				4-5 10	2-4 10								
21			2-4 11	4-5 11								4-4 11	3-5 11
21			4-5 10	4-4 10	3-3 10								
22											4-5 10		
22			4-4 10	3-5 10								4-5 11	3-5 11
22				4-5 11				*4-5 11*					
23			3-5 11	2-5 11								2-5 11	3-5 11
23			3-3 11	3-5 11	3-5 11						4-4 11		
23						2-5 10							
23											4-5 10		
23			4-5 11	2-5 11	3-4 11								
24			3-3 10	3-5 10	3-3 10								3-5 11
24						4-5 10							
24			4-4 11	4-5 11	2-4 11								
24			3-4 11	4-5 11									
25						3-5 10							
25			4-5 11	4-4 11									
25			4-4 10	4-5 10	2-3 10								
25			4-5 10	4-3 10									
26			4-5 10					4-5 10		3-4 11			
26			4-5 10	3-4 10	3-3 10								
26				3-5 11	4-5 11								
27			3-5 11	3-5 11						2-4 11			
27				3-5 10	2-4 10								
27				4-4 11	4-5 11								
27			3-3 11*	4-5 11*	3-5 11*								
28				4-5 10	2-4 10					3-4 11			
28			4-4 11	3-5 11	3-3 11								
28			3-2 11	4-5 11	3-5 11								
29			3-3 11	4-5 11						2-5 11			
29			4-3 11	4-4 11	3-3 11								

29				4-5 11									
30				4-5 11	3-3 11								4-5 11
30			4-2 11	4-5 11	4-5 11								

December 1989 AVHRR Coverage From JIC LAC and HRPT Hard Copies

Note - Every pass has its own line (within W. Arctic or E. Arctic). Those not found in the NOAA catalogue are not recorded here.

			Western Arctic (JIC designation)						Eastern Arctic (JIC designation)				
	Grid 1	Grid 2	Beaufort	Chukchi	East Siberian	Laptev	Lincoln	Central Arctic	Central Arctic	Lincoln	Kara	Barents	Greenland
Date													
1					4-5 10*			4-5 10*				4-5 11	3-5 11
1			3-3 11	3-5 11						3-5 11			
1			3-3 11*	4-5 11*	4-4 11*								
2			3-4 10	4-5 10								4-5 11*	4-5 11*
2			3-5 11	2-3 11						3-3 11			
2			4-3 11*	3-5 11*	4-5 11*								
2				4-5 11				4-5 11					
3			3-4 10	4-5 10								4-5 11	4-5 11
3			4-5 11					4-5 11					
3			3-4 11	4-5 11									
4										4-5 11*			
5			3-5 10	3-5 10						4-4 11*			
6						4-5 10*				3-4 11			
7			4-5 11	3-5 11						4-4 11*			
7			5-4 11	3-5 11	3-4 11								4-5 11
7			3-4 11	4-5 11									
7			~~4-5 10*~~					~~4-5 10*~~					
8			4-5 11	4-4 11						5-4 11*			
8			3-5 11	2-5 11									
8			4-5 10	3-5 10									
9			3-3 10	3-5 10								4-5 11	4 5 11
9										4-4 11			
10			5-5 11*	4-4 11*						3-2 11			
10			4-5 10	4-3 10								3-5 11	
10			4-3 11*	4-5 11*	4-4 11*								
11			3-3 11	4-5 11	4-3 11					4-5 11			
11				4-3 10	3-4 10							3-5 11	4-5 11
11			5-4 11	4-5 11									
12			5-5 10*					5-5 10*		3-5 11			

12			4-2 11	4-5 11	3-4 11								3-5 11
12			4-4 11	4-5 11								3-5 11	3-5 11
13			3-4 10	4-5 10	4-2 10					4-5 11*			
13			4-4 11	3-4 11									3-5 11
13												3-5 11	4-5 11
13					5-4 10*			5-4 10*					
14			5-5 11*	4-3 11*									4-3 11
14			4-5 10	4-4 10							4-4 10		
14			5-4 11	3-5 11									
14					3-5 11								
14					4-3 10	4-5 10							
15			5-5 11*					5-5 11*		4-4 11			
15			5-5 10					5-5 10					
15				2-2 11	3-5 11								
15			5-5 11										
16			4-4 11										4-4 11
16			4-3 11	1-5 11	3-3 11					4-3 11			
16													4-3 11
17					3-4 10								3-3 11
18													4-4 11
18													4-5 11
19					4-5 10								4 4 11
19			3-2 11	4-5 11	3-5 11					2-4 11			
19												4-5 11*	4-5 11*
20													5-5 11
20													4 4 11
20										3-4 11			
21					4-5 10*			4-5 10*			4-4 10		
21			2-2 11	4-5 11				2-2 11					4-5 11
21			2-2 11	3-4 11	4-5 11					4-5 11			
21				4-5 10				4-5 10					
22				3-5 11				3-5 11		5-4 11*			
22													3-5 11
23			3-3 11	4-5 11	2-5 11					2-4 11			

23			4-5 10										2-4 11
24				4-5 11				4-5 11		2-4 11			
24					4-5 11								
25				4-3 11*	4-5 11*					3-4 11			
26				3-4 11	3-5 11					4-5 11			
28			2-2 11	4-5 11	1-4 11								
28			3-4 11	3-3 11									
29			4-5 11							2-5 11*			
30			3-4 11	3-4 11	2-2 11					2-5 11			
31				4-5 10				4-5 10		3-5 11			

```
c       Convert_xy_ll
c
c       This program converts from Leads ARI grid sample,line
c       indexes to polar stereographic SSM/I grid coordinates
c       (in km) and to latitude and longitude.  This program is a
c       version of the program written by C.S. Morris, Jet Propulsion
c       Laboratory,  which appears in the NSIDC SSM/I User's
c       Guide, Section F, "SSM/I Polar Grids".
c
c       Program adapted for Leads ARI grids by F.Fetterer,
c       NOARL Remote Sensing,Stennis Space Center, March 1991

        real*4 x,y,alat,along
        real*8 e,e2,cdr,pi
        character*1 grid

c       Conversion constant, degrees to radians:
        cdr=57.29577951
c       Radius and eccentricity of earth (Hughes ellipsiod, km):
        re=6378.273
        e2=0.006693883
        e=SQRT(e2)
        pi=3.141592654
c       Standard parallel - latitude of no distortion
        slat=70.0
c       Puts 135 deg long. at the top of the grid:
        xlam=-45.

        print*,'Type ''P'' for Pacific grid, ''E'' for European'
        accept*,grid
 100    print*,'Type sample, line (9999,9999 to stop)'
        accept*,sample,rline
        if (sample.eq.9999.) goto 999
c       Transform sample, line coordinates to SSMI grid coordinates
        if(grid.eq.'P'.or.grid.eq.'p')then
         y=1975-rline
         x=-(2250-sample)
        else
         y=1300-rline
         x=sample
        end if
c       Comput latitude and longitude:
 200    rho=SQRT(x**2+y**2)
        if(rho.gt.0.1)goto 250
        alat=90.
        along=0.
        goto 300
 250    cm=COSD(slat)/SQRT(1.-e2*(SIND(slat)**2))
        t=TAN((pi/4.)-(slat/(2.*cdr)))/((1.-e*SIND(slat))/
     & (1.+e*SIND(slat)))**(e/2.)
        t=rho*t/(re*cm)
        chi=(pi/2.)-2.*ATAN(T)

        alat=chi+((e2/2.)+(5.*e2**2./24.)+
     & (e2**3./12.))*SIN(2*chi)+((7.*e2**2./
     & 48.)+(29.*e2**3/240.))*SIN(4.*chi)+
     & (7.*e2**3./120.)*sin(6.*chi)

        alat=alat*cdr
        along=xlam+ATAN2D(x,-y)
        if(along.lt.0.) along = along+360.
        if(along.gt.360.)along = along-360.
 300    print*,'   Sample   Line       SSMI x      SSMI y    Lat
     &     Long'
        write (6,310)sample,rline,x,y,alat,along
        print*

        goto 100
 310    format(4f10.2,2f10.4)
 999    continue
        end
```

```
c       Convert_ll_xy
c
c       This program converts from latitude and longitude
c       to polar stereographic SSM/I grid coordinates (in km)
c       and to Leads ARI grid sample,line indexes.  This program is a
c       version of the program written by C.S. Morris, Jet Propulsion
c       Laboratory,  which appears in the NSIDC SSM/I User's
c       Guide, Section F, "SSM/I Polar Grids".
c
c       Program adapted for Leads ARI grids by F.Fetterer,
c       NOARL Remote Sensing,Stennis Space Center, March 1991

        dimension t(2)
        real*4 x,y,alat,along
        real*8 e,e2,cdr,pi
        character*1 grid

c       Conversion constant, degrees to radians:
        cdr=57.29577951
c       Radius and eccentricity of earth (Hughes ellipsiod, km):
        re=6378.273
        e2=0.006693883
        e=SQRT(e2)
        pi=3.141592654
c       Standard parallel - latitude of no distortion
        slat=70.0
c       Puts 135 deg long. at the top of the grid:
        xlam=-45.

        print*,'Type ''P'' for Pacific grid, ''E'' for European'
        accept*,grid
100     print*,'Type latitude, longitude (9999,9999 to stop)'
        accept*,alat,along
        if (alat.eq.9999.) goto 999
        if(alat.lt.89.995)goto 250
        x=0.
        y=0.
        goto 300
250     rlat=alat
        do 600 II=1,2
         if(II.eq.2)rlat=slat
600     t(II)=TAN((pi/4.)-(rlat/(2.*cdr)))/((1.-e*SIND(rlat))/
     &  (1.+e*SIND(rlat)))**(e/2.)

        cm=COSD(slat)/SQRT(1.-e2*(SIND(slat)**2))
        rho=re*cm*t(1)/t(2)
        x=rho*SIND(along-xlam)
        y=-rho*COSD(along-xlam)
c       Transform sample, line coordinates to SSMI grid coordinates
300     if(grid.eq.'P'.or.grid.eq.'p')then
         rline=1975-y
         sample=x+2250
        else
         rline=1300-y
         sample=x
        end if
        print*,'    Sample   Line       SSMI x      SSMI y    Lat
     &      Long'
        write (6,310)sample,rline,x,y,alat,along
        print*
        goto 100
310     format(4f10.2,2f10.4)
999     continue
        end
```

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Mr. Gary Wohl
4301 Suitland Road
Washington, DC 20395

NOARL
Code 100
125L (10)
125P
200
222 (P. Bucca)
242 (D. Ramsdale, C. Mire)
300
320
321 (150)
322 (R. Preller, P. Posey)
Stennis Space Center, MS 39529

NOARL
Code 332
Attn: Dr. James Clark
Dr. Duane Eppler
Mr. Dennis Farmer
72 Lyme Road
Hanover, NH 03755-1290

Atmospheric Directorate
Attn: Dr. John Hovermale
Dr. Robert W. Fett
Dr. Steve Payne
Monterey, CA 93943-5006

Oceanographer of the Navy
Chief of Naval Operations
Attn: OP-096B (R. Feden)
OP-961E2 (J. Malay)
U.S. Naval Observatory
34th and Massachusetts Ave., NW
Washington, DC 20390-5100

Office of Naval Research
Attn: Dr. T. Curti
Dr. C. Lutl
800 N. Quincy Stre
Arlington, VA 22217-5000

Office of Naval Technology
Attn: Dr. M. Briscoe, Code 228
800 N. Quincy Street
Arlington, VA 22217-5000

Planning Systems, Inc.
Attn: Dr. R. L. Crout
115 Christian Lane
Slidell, LA 70458

SAIC
Attn: Dr. B. Walter
13400B Northup Way
Suite 36
Bellevue, WA 98005

Space and Naval Warfare Sys Com
Attn: CAPT Carl Hoffman
LCDR Bill Cook
Code PMW-141
2511 Jefferson Davis Hwy
Washington, DC 20363-5100

U.S. Naval Observatory
Attn: Mr. Donald Montgomery
34th and Massachusetts Ave., NW
Washington, DC 20392-1800